ELECTRONICS EDUCATION IN COMMUNIST CHINA

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ELECTRONICS EDUCATION IN COMMUNIST CHINA

/Following are translations of three
articles appearing in Wu-li T'ung-pao
(Physics Bulletin), No 4, Peiping, 1960./

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WIRELESS TELEPHONE TRANSMITTER

/Following is a full translation of an
article written by Shen Chin-chen appear-
ing in Wu-li T'ung-pao (Physics Bulletin)
No 4, Peiping, 1960 pages 188-189./

In the teaching of physics in the third year of
higher middle school, a difficulty was felt by the teachers
and students in studying the cahpter of electromagnetic
oscillation, especially in the section of electromagnetic
wave transmitting. It is often due to the lacking of
teaching equipment that the teachers' explanation and the
students' understanding become a problem. Although we can
use the induction coil and neon tube now in hand to con-
struct the simplest sparking type of transmitter to solve
part of the difficulty, this kind of teaching equipment
cannot explain the modulation effect in a wireless tele-
phone transmitter. To solve the above-mentioned problem,
the following three simple, experimental circuits have
been especially recommended for reference of comrades.

(1) The simplest wireless telephone transmitter is
to convert the three-circuit regenerative receiver. A
wireless telephone transmitter is made by connecting a
carbon microphone in series in the antenna circuit with
the antenna-modulation method. Construction is shown as

figure 1. When operating this transmitter, the first thing to do is tune the regenerative, variable condenser C, starting from low capacity and slowly increasing the capacity until oscillation occurs. (In the headphone a sound like "p'eng" may be heard. If there is a squeal it is because the oscillation frequency is close to the oscillation frequency of a radio station nearby. Now, in order to change the oscillation frequency, tune C_1). If one speaks toward the carbon microphone S, the modulated wave is thus transmitted.

This wireless telephone transmitter may be installed on the platform in a classroom for broadcasting and a five-tube receiver AC or DC may be used to receive the broadcasting at a student seat or in another room. But this three circuits regenerative oscillation is not powerful, and the result in receiving is not too good. However, it is simple in construction and convenient to make and install.
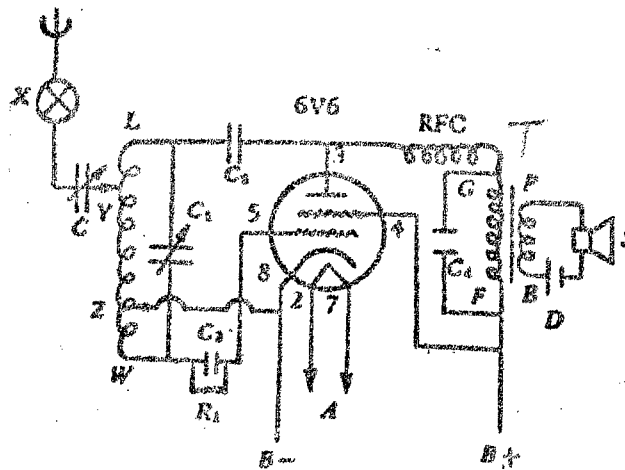
Key:

1. Antenna
2. Microphone
3. Three-circuit coils
4. Ground wire
5. 1 megohm
6. Headphone

Figure 1

(2) Furthermore, a simple transmitter (as shown in figure 2) which is comparatively better, is the plate-modulation method. The result produced from this kind of transmitter is better than the antenna-modulation method mentioned previously. Broadcasts from this transmitter can be received with a five-tube receiver at a distance of several tens of meters or even farther, if the electron tube used in the transmitter is the 6V6 type or the like, which is the power amplifier tube in the last stage of an ordinary five-tube receiver.

Figure 2

In the figure: C and C_1 are 0.00036uF variable condensers; C_2 is a 0.002uF fixed condenser; C_3 is a 0.0005uF fixed condenser; and C_4 is a 0.01uF fixed condenser. R_1 is a 10,000 ohm resistor. T is a low frequency transformer; /with a ratio/ 1:3.5 may be used, but it is best to convert it into a 1:30 transformer. S is a carbon microphone. D is a 2-3v battery. RFC is a high frequency choke coil (or wind 200 turns of varnished wire around a brush pen holder instead). The /voltage of/ A battery and B battery will depend upon which elecyron tube is being used. If the type 6V6 is used, A battery will be 5 volts and B battery will be 100-200 volts. L may use thick copper wire winding around a ceramic tubing, or use the high leg insulators winding in the air, and the number of

turns will be decided by experiments.

A short wave band in a five-tube receiver can be used to receive the broadcast if L is at about 10 turns. X is a small electric light bulb. When C, C_1, Y and Z are adjusted to some suitable position (for example: LY, 2 turns; YZ, 6 turns; ZW, 2 turns; and one half of C and C_1 adjusted out) and when the small electric light bulb is aglow, the electromagnetic-wave transmission is clearly demonstrated.

A 5-10 meter long insulated wire set up on bamboo poles with insulators may be used as an antenna. (During experiment, if the small electric light bulb still cannot glow even C is adjusted all in, the length of the antenna should be increased).

The result will be more satisfactory if one or two stages of electron tube amplifiers will be added after the carbon microphone in this wireless telephone transmitter.

(3) Besides this, there is another kind of grid-modulation transmitter of which the construction is about the same as in figure 2. The only difference is that the transformer for modulation use is installed in the grid circuit as in figure 3. This kind of modulation method can also obtain very good results even under conditions

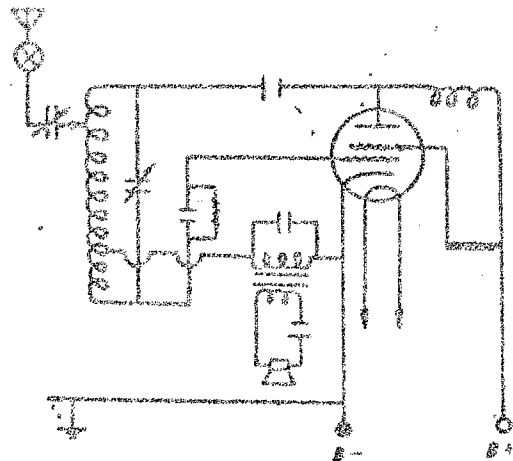where the power input at the microphone is comparatively small.

Figure 3

As to the power source, storage batteries may be used for A and B. If three 2-volt storage batteries are connected in series, a 6-volt battery will be made for A. If two 100-volt battery-boxes are connected in series, a 200-volt battery will be made for B. If there is no storage battery in the school but there is AC source, a transformer used for a five-tube receiver and rectifier tube 5Z3 or the like, can be constructed as shown in figure 4. In this figure: AFC is a low frequency choke coil and R is a 25,000 ohms resistor. The resistor should have a bigger wattage, otherwise it will burn out when overheated.
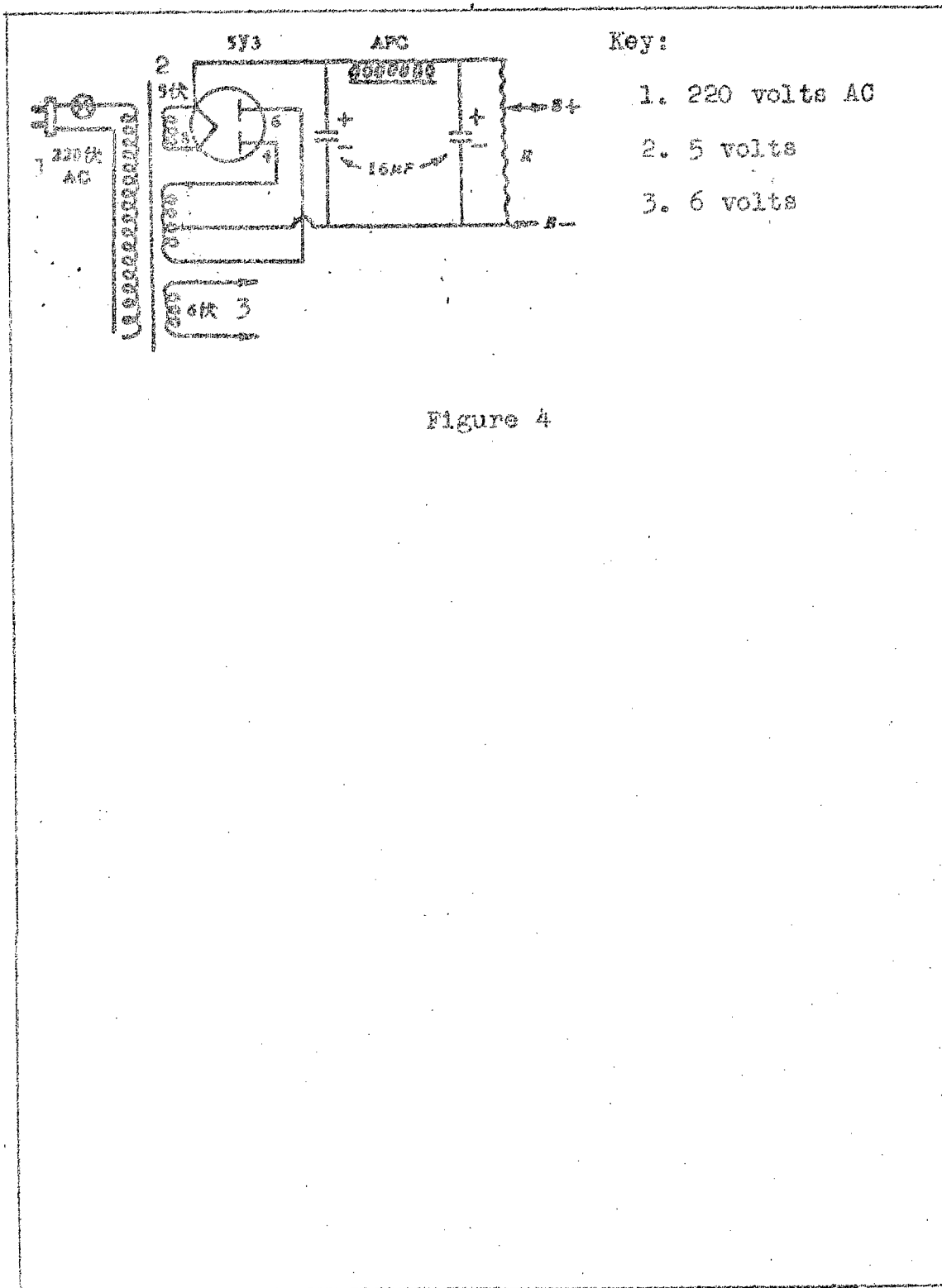
Figure 4

Key:

1. 220 volts AC

2. 5 volts

3. 6 volts

NOISE CHARACTERISTICS OF ELECTRONIC DEVICES

/Following is a full translation of an arti
article by Ch'eng Tsung-chih appearing
in Wu-li T'ung-pao (Physics Bulletin)
No 4, Peiping 1960, pages 158-162.7

I. Noise and its importance.

In the communication system, the undesired signals
generally are all designated as noise. For example: in a
radar system, the signal wave is transmitted by a trans-
mitter to survey certain objects, but after it is reflec-
ted, the receiver receives not only the reflected wave but
also other electric energy. Except for the reflected
wave, those undesired signals are usually called noise.
Another example is that an ordinary broadcast receiver re-
ceives not only the broadcasting program but also some
other sound with it. That undesired sound besides the
program is also generally called noise. One more example
is that the degree of clarity in a mutual conversation,
which is the signal, in a textile mill is affected by the
loud noise from running machines or other sounds. Gener-
ally it is said that the mill's noise is very loud.

There are many noise sources. In an ordinary
receivering system, the main source of noise usually comes
from electronic devices, such as electron tube amplifiers,

crystal mixers, and transistor amplifiers, etc. The magnitude of noise is closely related with the characteristics of a receiving system. A receiver with low noise has high sensitivity, or, in other words, it could receive relatively weak signals. Generally, speaking, a sensitive receiver is suitable for comparatively long distance communication. Therefore, the research in noise and means to reduce noise have been crucial problems in long distance communication.

Besides the communication system, low noise characteristic devices are also required in surveying equipment such as mine detectors in geophysical prospecting.

The demand for low noise characteristic electronic devices is more urgent from time to time in new types of technology and subjects, such as radio astronomy, long distance radar, interplanetary travelling and infra-red communication. Noise in electronic devices is therefore an important characteristic. Research work is now being developed in a wide scale. There are various types of new equipment with low noise characteristics produced continuously.

In this article, the source of noise, comparison of different expressions in noise /calculations/, ways to reduce noise and various kinds of low noise devices are

briefly introduced.

II.   The Sources of Noise in Electronic Devices.

Noise in electronic devices is caused by the random motion of electrons. The most important noises are thermal noise and shot noise. These two kinds of noise are present in all kinds of electronic devices while the flicker noise, partition noise and semiconductor noise are presented in certain electronic devices only.

(1) Thermal noise.

Thermal noise is termed as the noise generated by the random motion of electrons in a resistor due to thermal agitation. According to statistical mechanics, the average mean square value of thermal noise emf can be calculated as

$$\overline{v^2} = 4KTRB.$$

In the equation, K is Boltzmann's constant which is equal to 1.3805×10^{-23} watt·second·absolute temperature^{-1};

T equals temperature, absolute;

R equals resistance, ohms;

B equals bandwidth, cycles.

Thus the noise in a resistor can be expressed with a noise emf source $\sqrt{\overline{v^2}}$ connected in series with the resistor, or a noise current source $\sqrt{\overline{i^2}}$ connected in

parallel with the resistor as shown in figu

$$\sqrt{\overline{i}^2} = \sqrt{\frac{4KTB}{R}}$$

A resistor with   noise   noise
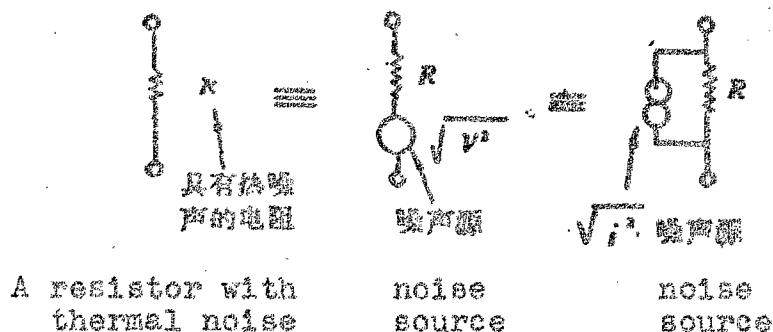thermal noise   source   source

Figure 1. Equivalent circuits for the
description of the noise in resistors.

Due to thermal noise, the effective noise power P_a
is expressed as

$$P_a = \frac{\overline{V}^2}{4R} = KTB$$

Wherever resistance is presented in any electronic
device, a respective thermal noise is also presented. The
effective noise power is proportional to absolute tempera-
ture and the frequency bandwidth. Effective noise power
can be reduced by decreasing the temperature.

(2) Shot noise.

In a diode, the formation of a current is due to
electrons emitted from a cathode toward an anode. The

production of noise is caused by the random emission of electrons from a cathode and the random arrival of electrons at an anode which is termed as shot noise. In a temperature-limited diode, the mean square value of the noise current is

$$\bar{i}^2 = 2eIB$$

In this equation, e is the electronic charge; I is the DC current; and B is the noise frequency bandwidth.

In a space-charge-limited diode it is

$$\bar{i}^2 = 2r_e^2 IB$$

In this equation, r_e^2 is the space-charge suppression factor, and it is usually in a range from 0.01 to 0.1.

Shot noise is present in ordinary electronic devices such as electron tubes, semiconductor diodes and other transistors. It is an important noise source in electronic devices.

(3) Other electron tube noises.

Besides thermal noise and shot noise, there are many other noises in electron tubes. For example, in multi-electrode tubes the electrons emitted from a cathode toward an anode or other electrodes are distributed at random between different electrodes. This type of noise

is known as partition noise. If there is a little trace of gas in an electron tube, the noise due to random collision of ions is known as ionization noise. The random emission of electrons from the phenomenon of secondary emission is termed secondary emission noise. Noise due to slow fluctuations in random emission of a cathode is known as low frequency flicker noise, etc. This group of noise sources will increase the total noise in an electron tube.

(4) Noise in semiconductors (3-4).

The main noise sources in a semiconductor are thermal noise and shot noise. Then there are low frequency noise sources which are termed surface noise and leakage noise. For example: In a pnp transistor, most of the holes emitted from the emitter will diffuse themselves into the base and go forward to the collector. Still there is a very small part which recombines inside the base or recombines at the surface of the emitter and the base. Noise due to the surface recombination is called surface noise. Leakage-conductance-and-leakage phenomena are formed at the junction of the collector, which is another source of noise resulting from poor technique in manufacturing. This type of noise is called leakage noise. These two kinds of noise have about the same characteristics as flicker noise which is $1/f^r$ (figure 2)

(r is about equal to 1). They are all called excess noise.

If a good semiconductor device is operating at a high frequency range excess noise will not be the main noise but thermal noise and shot noise will be.
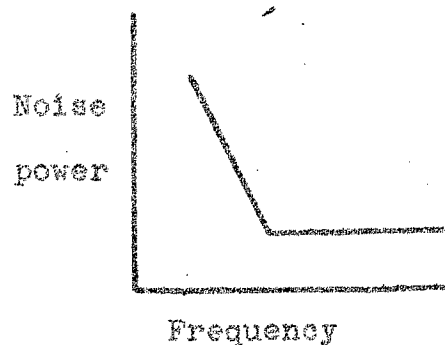
Noise
power

Frequency

Figure 2. The relation between excess noise and frequency.

III. The Methods to Express Noise

Certain noises are presented in certain electronic devices. In the design of low frequency applications, in addition to emphasizing many characteristics, such as power gain, frequency range response, input and output impedance, the noise characteristic should be also understood. There are many ways to express the noise characteristics and form noise performances for comparison of advantages and disadvantages of different electronic devices. Noise performances most often used are the

noise factor and the effective noise temperature.

    (1) Noise ratio n.

    It is because of the production of a random amount of noise that people in general are interested in calculating noise power. If N_0, the effective output noise power of a certain electronic device within a certain frequency bandwidth, divided by the effective thermal noise output power within the same frequency bandwidth, is called noise ratio n, then

$$n = \frac{N_0}{KT_0 B}$$

    In this equation T_0 is the environmental temperature which is usually room temperature 17°C [sic], that $T_0 = 290°K$.

    If an electronic device has a higher noise, then its effective noise output power should be bigger and the noise ratio n should also be bigger.

    (2) Equivalent noise resistance

    The noise of any electronic device could be expressed by its equivalent noise resistance. For example: it is usually by connecting a resistance between a cathode and a grid of an electron tube that the noise characteristic of that tube is expressed and it is called the equivalent noise resistance. After the thermal noise of

this equivalent noise resistance has gone through amplification and become the effective noise power, the same noise power will be equal to the effective noise power of the tube itself.
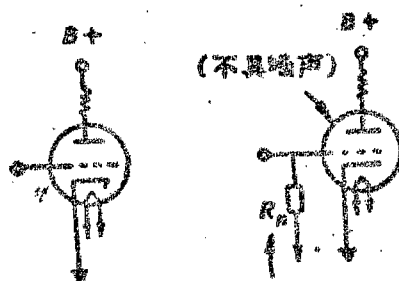
An electron tube with noise.

This equivalent noise resistance is used to represent the noise in the tube.

Figure 3. Equivalent Noise Resistance

In a triode, the equivalent noise resistance R_n is

$$R_n \cong \frac{2.5}{g_m} \text{ ohm}$$

In this equation, g_m is the mutual conductance, mhos.

In a pentode, the equivalent noise resistance R_n is

$$R_n \cong \frac{2.5}{g_m i_s} I_p \left(1 + 8 \frac{I_2}{g_m}\right) \text{ ohms.}$$

In this equation:

I_p is the plate current, ampere;

I_g is the cathode current, ampere;

I_2 is the screen grid current, Amp.

g_m is the mutual conductance, mhos.

If the noise is large in an electron tube, its equivalent noise resistance is also large. For low noise applications, an electron tube with low equivalent noise resistance should be selected.

(3) Noise factor

There is a certain ratio required in the amplifiers or receiving systems made from any electronic devices. It is the output signal power S_0 to the output noise power N_0 . For example: in a good communication system, signal to noise ratio is 20 decibels and an inferior system may use 10 decibels. In-put signal power to the input noise power ratio divided by the output signal power to output noise power ratio is called the noise factor. That is

$$F = (\frac{S_i}{N_i}) / (\frac{S_0}{N_0})$$

In this equation S_i , N_i , S_0 , and N_0 will all be effective powers when the amplifier operates at matching conditions regarding its input power and output power. The gain of an amplifier G (figure 4), also is

$$G = \frac{S_0}{S_i}$$

Key:

1. Amplifier

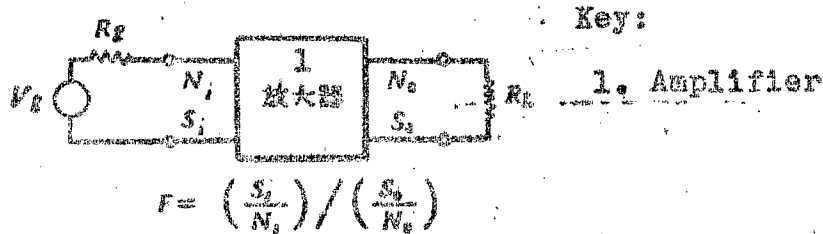$$F = \left(\frac{S_i}{N_i}\right) / \left(\frac{S_0}{N_0}\right)$$

Figure 4. The Definition of the Noise Factor.

If the amplifier is an ideal amplifier, in that no noise is generated within itself, then the ratio of output signal power to input signal power will be G, and the ratio of output noise power to input noise power is also G, that is

$$S_0 = GS_i \qquad\qquad N_0 = GN_i$$

so that $\qquad\qquad F = 1$

Taking the logarithm $\quad F = 10 \log_{10} F_{ratio} = 0$ decibel.

Thus the ideal amplifier which generates no noise within itself has a noise factor of 1, or 0 decibel. In fact, all amplifiers have some noise generated within themselves and any noise factor is bigger than 1 or higher than 0 decibel. The noise factor can thus express the noise characteristic of an electronic device. When the noise is high, the noise factor is large.

In a real amplifier:

$$S_O = GS_i$$

$$\text{and } N_O > GN_i, \qquad N_O = GN_i + N'$$

In this equation, GN_i is the output noise power which is input noise power after amplification, and N' is the component of the output noise which is produced by noise sources within the device. The noise factor is

$$F = \frac{N_O}{GN_i} = \frac{GN_i + N'}{GN_i} = 1 + \frac{N'}{GN_i}$$

$$F - 1 = \frac{N'}{GN_i}$$

Therefore $F - 1$ is expressing the ratio of the component of the indicated output noise power to the output noise power.

Because of the noise characteristic related to the frequency and the frequency bandwidth, it is necessary to define the center frequency and the effective noise frequency bandwidth while the noise factor is being studied.

(4) Effective noise temperature

In recent years, effective noise temperature is often used to express noise performance. According to the noise factor deduction, we have

$$F - 1 = \frac{N'}{GN_1} = \frac{\left(\frac{N'}{G}\right)}{N_1} = \frac{N_i'}{N_1}$$

Thus the value of $F - 1$ is really related to the output noise power which is produced by noise sources within the device (at the output it is N' and at the input the equivalent effective is N_i' which equals to N'/G). If the value

$$f'' = F - 1,$$

then f is the overall effective noise temperature.

If the input noise power N_1 comes from thermal noise at room temperature, then

$$N_1 = KT_0B$$

If the effective noise of an electronic device is expressed by an equivalent thermal noise, then

$$N_i' = KT_eB$$

Therefore $\quad f = F - 1 = \dfrac{KT_eB}{KT_0B} \quad \dfrac{T_e}{T_0}$

In this formula, T_e is the effective noise temperature, and T_0 is room temperature ($T_0 = 290^\circ C$), so

$$T_e = 290 (F - 1)$$

In this equation F is the noise factor (ratio), and T_e is the effective noise temperature ($^{\circ}$K). According to the above equation, the correlation between the noise factor (decibel) and the effective noise temperature could be found. For instance, when F = 1 decibel, T_e = 75.5° K; if F = 3 decibels, then T_e = 288°K.

Recently, the development of microwave low noise amplifiers has been very fast. For instance, the resonant-cavity quantum amplifier has a noise factor as low as 0.03 decibel at 3000 megacycles. The effective noise temperature is as low as 2°K. In the microwave range, the semiconductor with a variable capacitance parametric amplifier has a noise factor as low as 0.4 decibel, and the effective noise temperature is as low as 28°K.

(5) Noise measure (5)

Suppose there were two stages of amplifiers connected in cascade (figure 5), or one mixer stage and one amplifier stage were connected in cascade, and if the gain of the first stage is G_1 and its noise factor is F_1 the gain of the second stage is G_2, and its noise factor is F_2, then the overall noise factor F_{12} is

$$F_{12} = F_1 + \frac{F_2 - 1}{G_1}$$

If the second amplifier now is changed to the input end,
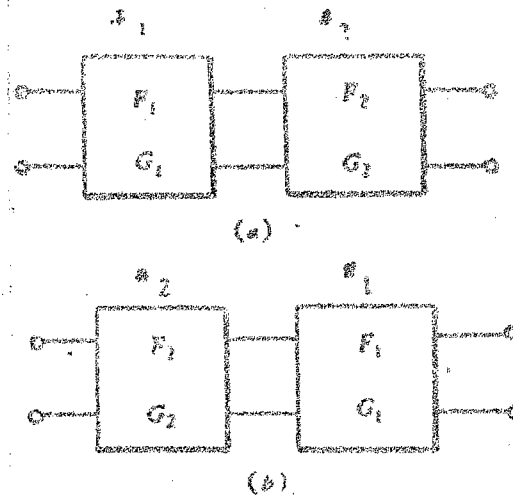
21

as in figure 5b,

(a)

(b)

Figure 5.   The Block Diagram of Two
Stages Connected in Cascade.

Then the overall noise factor of these two stages is

$$F_{21} = F_2 + \frac{F_1 - 1}{G_2}$$

If in either way of the cascade these two stages
are matched to each other, then the overall gain will be
equal.   That is

$$G_{12} = G_1 G_2 = G_{21}$$

How can a parameter be used to express the above-
mentioned two ways of cascade-connection in which one way
is better than the other in the noise characteristics?   A
new performance is needed.   This is the reason that the

noise measure comes into view.

Suppose the cascaded connection shown in figure 5_a has a higher overall noise factor than shown in figure 5_b. That is

$$F_{12} > F_{21}$$

also

$$F_1 + \frac{F_2-1}{G_1} > F_2 + \frac{F_1-1}{G_2}$$

in the above equation, minus 1 on both sides, we obtain

$$F_1-1 + \frac{F_2-1}{G_1} > F_2-1 + \frac{F_1-1}{G_2}$$

rearrange the above equation:

$$\frac{F_1-1}{1-\frac{1}{G_1}} > \frac{F_2-1}{1-\frac{1}{G_2}}$$

Let M be the noise measure for one amplifier,

$$M = \frac{F-1}{1-\frac{1}{G}}$$

Then $M_1 > M_2$

Therefore when $F_{12} > F_{21}$, $M_1 > M_2$; that is, in order to obtain a lower noise characteristic, the device with less M should be placed at the first stage.

Noise measure is a kind of performance. It is used to decide as to which is the first stage in a cascaded connection. At present this performance has not been widely used.

(6) Equivalent noise circuit

The characteristic of an electronic device can be expressed by its equivalent circuit. The noise characteristic can also be suitably expressed by an equivalent noise source and an equivalent circuit for this noise characteristic can thus be drawn. According to this equivalent circuit, the other elements such as the methods of connection, signal source and load, etc. which may affect the noise characteristic may be inferred.
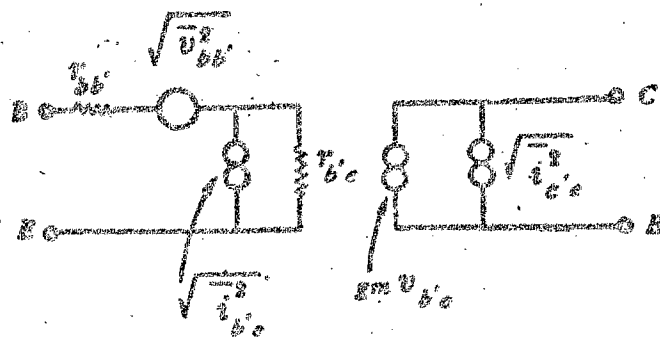

Figure 6. Transistor equivalent circuits.

Figure 6 is a kind of transistor equivalent circuit. In this figure, $r_{bb'}$ is the spreading resistance of the base; $\sqrt{\overline{v_{bb'}^2}}$ represents the thermal noise gen-

erator which comes from resistance $r_{bb'}$; $r_{b'c}$ represents
conductance inside the transistor between the emitter and
the base; $\sqrt{\overline{i_{b'c}^2}}$ represents the equivalent noise cur-
rent generator which comes from the surface noise; and
$\sqrt{\overline{i_{cc}^2}}$ represents the equivalent noise current generator
which comes from the leakage noise. Following the equi-
valent circuit, different kinds of noise characteristics
of a transistor could be calculated.

IV. The Principal Methods to Reduce Noise

Reduction of noise is one of the necessary steps
to satisfy the requirement for sensitivity in a receiving
system. Following are the principal methods for the reduc-
tion of noise from electronic devices.

(1) Research in trial manufacturing of low noise
devices /is now going on/. These devices include the
newly made quantum amplifier in the microwave devices, the
semiconductor diode with variable capacitance parametric
amplifier, and the electron beam parametric amplifier etc.
They all possess low noise characteristics.

(2) Improvement of the noise characteristics in
electronic devices already established /in the market/.
These include the manufacturing of extraordinarily low
noise transistors and electron tubes, and the elimination

of the leakage noise source and the surface noise source, etc., from transistors so as to improve noise characteristics.

(3) Operation of the electronic devices under suitable low temperature conditions so that the temperature-related thermal noise may be reduced and that the noise characteristics may be improved.

(4) Operation of the signal source at low temperature conditions. An antenna is the signal source in a preamplifier or in a mixer stage which is usually expressed by an equivalent antenna resistance. Reduction of the equivalent /noise7 temperature will help to improve noise characteristics.

(5) Operation of circuit elements at optimum conditions. The operating voltage in an amplifier, operating current and matching requirements are all related to noise characteristics. To find the best optimum noise operating conditions is to select a suitable operating point, circuit combinations and matching conditions.

(6) If certain parts of other circuits are utilized it may help to reduce noise in a system. For example: if in a microwave amplification, a rotating device is used, the noise characteristic of a system will be reduced, for noise thrown back from the load will not

be amplified. The total noise is thus reduced.

Nevertheless, because of the importance of low noise devices and low noise receiving systems, efforts are being made in many ways to reduce the systems' noise characteristics of electronic devices, circuits, systems and related parts and operate them in suitable environmental conditions. These efforts will boost sensitivity and increase the communication systems' distance. Progress in this line of work is being made rapidly.

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EXPERIMENTS CONDUCTED WITH THE USE OF ELECTRON TUBES

/Following is the full translation of
an article written by "Ma-Erh-Ko-Lin"
and translated by T'ang Wen-chih, ap-
pearing in Wu-li T'ung-pao (Physics
Bulletin) No. 4, Peiping, 1960, pages
184-185./

When tenth-grade students study the chapter on
"electromagnetic oscillation and electromagnetic waves"
they could understand only the application of electron
tubes to radio transmitting and receiving. In fact, in
modern technology, all electron tubes have exceedingly
wide-spread applications such as in all kinds of auto-
matic installations, equipment to control and regulate
machines, and in all kinds of measurement apparatus, etc.

In this article, two devices are described. These
two devices may be used to conduct experiments either in
the classroom or in after-class activities. The neces-
sary devices could be made completely by the students
themselves.

EQUIPMENT FOR EXAMINING METALLIC IMPURITIES.

The examination of metallic impurities in an insu-
lating material, is conducted technically with an elec-
tron tube oscillator. When the material being examined is

inserted into the coil winding of the oscillator, the
ammeter connected in the plate circuit will indicate an
increase in the DC component if there are impurities.
The reason for this is that the metallic current conduct-
ing substance inserted into the coil induces an eddy cur-
rent, so that the energy is absorbed from the oscillator.
The high frequency current amplitude (and the local fre-
quency) is decreased. This could be discovered by the
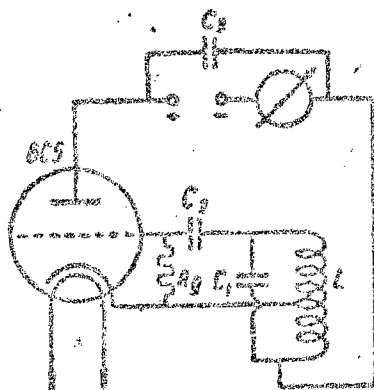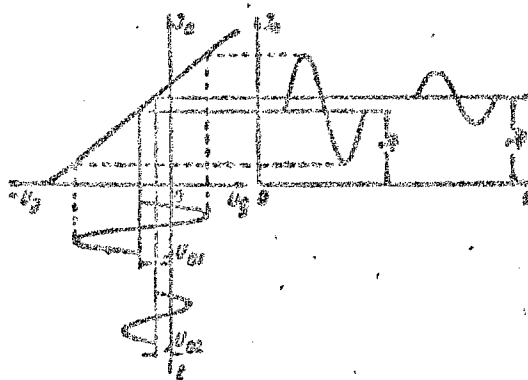increase of the DC component in the plate current. (Fig-
ure 1).

Figure 1

Figure 2

The apparatus is made according to the three-point-circuit oscillator. The coil L is made from 60 turns of 0.6-0.8 mm varnished copper wire. There is a lead at the 40th turn counted from the end where the plate is connected. The diameter of the coil is 30mm. The capacities of the different condensers are: C_1--120uuF, C_2--160uuF, and C_3--0.1uF. The grid leak resistance is 30,000 ohms. A 6C5 type of electron tube is used in this circuit. The direct voltage power supply comes from a rectifier with an output of 200-250 volts. The filament of the electron tu tube is also /heated7 by the rectifier. An ordinary demonstrating galvanometer is connected in the circuit and the indicating needle in the meter is adjusted at about the middle of the scale board when the plate current starts to flow.

The oscillator is installed on an upright control panel 25 x 40cm. All the parts will be installed on the front side of the control panel. At this time, the coil is vertically installed so that the material being examined in a test tube will be conveniently inserted into this coil.

The experiment procedure is: after the power supply is turned on, the oscillation circuit will start to oscillate. A testing coil connected with a 2-3.5v

small electric light bulb or a neon tube connected to the oscillating circuit leads will start /sic/ the oscillation. The reading from the meter in the plate circuit is now observed after the oscillation started.

When a test tube filled with clean sand particles is inserted into the coil, there will be no change noticed in the plate current. If 10 percent, 20 percent or any amount of iron fillings is mixed with the clean sand particles in the test tube, an increase in the plate current will be observed. The numerical value increased in the current is proportional to the percentage of the impurities added.

ELECTRON TUBE AMMETER

Electron tubes could be used to make sensitive ammeters. This kind of ammeter is able to measure 10^{-8} -- 10^{-9} amperes such as a photo electric current.

The principle of this apparatus is as follows: if a 10^{8} -- 10^{9} ohm resistor is connected in series in a grid circuit of an electron tube, an approximately 1-volt drop will be obtained in the circuit when the current I_g is 10^{-8} -- 10^{-9} amperes. A change in voltage at the grid ΔU_g will correspondingly introduce a change ΔI_a in the plate current. The change in plate current will be decided by

the formula:

$$\Delta I_a = S \Delta U_g$$

here S is the mutual conductance of the electron tube.
Thus the electron tube is able to obtain a current ampli-
fication:

$$K = \Delta I_a/I_g = S \Delta U_g/I_g$$

For an electron tube with mutual conductance $S =$
10^{-3} a/b, the numerical value of the coefficient of ampli-
fication may reach as high as $10^5 - 10^6$.

Among electron tubes often used today, 6Hr and 2n1n
are the most suitable tube types used for demonstrating
the electron tube ammeter. The 2n1n type of electron tube
should be used as a triode. The screen grid and the plate
will be connected together. The suppressor grid and the
cathode are also connected together. The most important
thing is that the insulating resistor between the grid
and cathode should be very big.

The fundamental circuit of this apparatus is shown
as figure 3. A 2n1n type of electron tube is engaged in
this circuit. The plate voltage is 50 volts supplied
from a set of dry cells. The two filament leads are con-
nected to the electric source with 2.4 volts or 1.2 volts

If 1.2 volts is used, one half of the filament should be
connected in parallel with the other half. The grid leak
resistor R_g will produce the effect of an insulating
resistor between the cathode and grid of the electron tube.
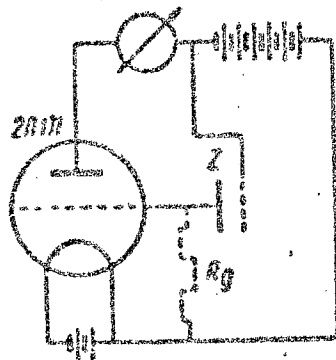

Figure 3

When we operate the electron tube under the speci-
fied conditions the plate current is about equal to 5ma,
the indicating needle of the ammeter will be tilted to one
end of the scale board. The adjuster should be used to
set the needle at about the middle of the scale board.

To demonstrate the photoelectric effect ("Ssu-t'o-
lieh-t'o-fu" experiment), a zinc plate is first connected
to the grid of the electron tube. In front of this zinc
plate, another net-like electrode is fixed. For the sake
of convenience, the asbestos wire gauze which a school
usually has can be used as a net-like electrode. The as-
bestos wire gauze should be thoroughly cleaned. It will

be connected to the positive terminal of the battery set.

These two electrodes can be fixed firmly on a table with the stand which is usually used to demonstrate the effect of variable condensers.

An electric arc shines on the zinc plate, 1--2 divisions on the scale will be increased in the ammeter. If the zinc plate has a mercury amalgam, the photoelectric effect will be more pronounced.

Translated by T'ang Wen-chih from "The teaching of physics" No. 6, 1956 Soviet Union.

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